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<p>(54) Title: FILTER</p>			
<p>(57) Abstract</p>			
<p>A filter comprising an array of bundles of open-ended filter tubes each housed within and extending along the length of a support tube. Filter tube seals are arranged at each end of each support tube such that the filter tubes extend therethrough, the seals preventing axial flow through the ends of the support tubes except through the filter tubes. A tubular housing receives each support tube, at least two conduits communicating with openings in each housing. Axially spaced annular seals located between each support tube and the associated housing divide the space defined between the support tube and housing into axially spaced regions which communicate with respective conduits. Openings in the support tubes communicate with respective conduits through the spaces between the housing and support tubes. One of the openings in each support tube communicates with the open ends of the filter tubes, and another communicates with the space within the support tube around the filter tubes and between the filter tube seals. The housings have removable covers which when removed leave apertures axially aligned with the support tubes to enable the insertion and removal of the support tubes in the axial direction. The covers may be transparent to enable visual inspection of the flow within the support tubes, and the housings may incorporate slidable plugs to enable the selective isolation of individual tube bundles.</p>			

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## **FILTER**

The present invention relates to filters, and in particular to filters incorporating bundles of filter tubes mounted in tubular supports. The filter tubes may be for example hollow fibres of the type used in microfiltration and ultrafiltration to remove particles from for example potable water.

It is an objective of the designers of filters to maximise throughput for a given filter pore size and pressure across the filter medium by maximising the effective surface area of the filter medium. To maximise the effective surface area for a given size of installation conventional filter design relies upon building filter assemblies in which large numbers of filter tubes are arranged in a parallel array. Generally, fluid to be filtered is pumped into the space around the filter tubes, and permeate is drawn from the interior of the tubes. In order to provide support for the filter tubes, which may be of small diameter, it is known to mount the tubes in bundles within support tubes. Such support tubes and fibre bundle assemblies have often been referred to as filter "inserts". Seals are provided at each end of the support tube to separate the permeate and retentate, the seals being formed from for example plugs of epoxy resin through which the open-ended filter tubes extend. Liquid to be filtered is pumped into the support tube through apertures located between the seals, and permeate is drawn from the ends of the tubes.

**The known tube bundle filters have been widely used, but the designers of such filters having encountered four particular problems. Firstly, the relatively large number of fibres in large installations, and the requirement that each filter tube and each support tube must be sealed, makes it difficult to ensure system integrity, that is the reliability of the separation of permeate from retentate. A leak in any filter tube or any seal will result in mixing between the permeate and retentate. In applications such as potable water purification filter integrity is of fundamental importance. Secondly, it is difficult to detect leaks between the permeate and retentate sides of the filter, and in the event that a leak is detected it is even more difficult to locate the source of that leak. Special instruments relying upon for example the detection of noise resulting from bubble formation have been developed, but such instruments are relatively complex and difficult to use. Particularly in large installations, this means that maintenance and repair is costly. Thirdly, if a leak is detected and located, it is difficult to rapidly isolate the leaking component without substantial system downtime. Fourthly, the reliable interconnection of a large array of filter tube bundles is difficult to achieve in a compact manner given that it must be possible to remove individual filter tube bundles for maintenance and repair.**

**It is an object of the present invention to obviate or mitigate the problems outlined above.**

**According to the present invention, there is provided a filter comprising at least one bundle of open-ended filter tubes housed within and extending along**

**the length of a support tube, sealing means arranged at each end of the support tube such that the filter tubes extend therethrough, the sealing means preventing axial flow through the ends of the support tube except through the filter tubes, a tubular housing which receives the support tube, at least two conduits communicating with respective openings in the housing, axially spaced annular seals located between the support tube and the housing to divide the space defined between the support tube and housing into axially spaced regions which communicate with respective conduits, at least two openings in the support tube located to communicate with respective conduits through respective regions of the space between the housing and support tube, at least one of the openings in the support tube communicating with the open ends of the filter tubes, at least one of the openings in the support tube communicating with the space within the support tube around the filter tubes and between the sealing means, and the housing having a removable cover which when removed leaves an aperture axially aligned with the support tube to enable the insertion and removal of the support tube in the axial direction.**

**With an arrangement in accordance with the invention as defined above, a bundle of filter tubes can be removed from an installation without it being necessary to disturb any of the other bundles of that installation. Thus assembly, maintenance and repair is a simple matter.**

**Preferably the housing comprises two axially aligned sealing tubes each of which receives a respective end of the support tube, each sealing tube being**

**connected to at least one conduit. Alternatively a single sealing tube may be provided the length of which exceeds the length of the support tube. The support tube may be open ended.**

**Preferably the housing is connected to first and second conduits which communicate with respective ends of the filter tubes and third and fourth conduits which communicate with opposite ends of the space defined within the tubular support between the sealing means. Means may be provided for directing a flow of fluid to be filtered into the third conduit and out of the fourth conduit such that particles deposited on the filter tubes are flushed out of the support tube to the fourth conduit. Alternatively, means may be provided for directing a flow of fluid to be filtered into the one or both of the third and fourth conduits and removing permeate from one or both of the first and second conduits, and for backwashing the filter tubes by directing a flow of backwash fluid into one or both of the first and second conduits and removing backwashed material from one or both of the third and fourth conduits.**

**The annular seals may be retained in circumferential grooves defined in the outer surface of the support tube. At least one annular seal may comprise a pair of axially spaced seals, a drain hole being defined in the housing between the pair of seals to enable fluid leaking past either of the pair of seals to escape from the housing. With such an arrangement leakage of one of the seals can readily be detected before there is any risk of fluid to be filtered becoming mixed with permeate.**

**Preferably removable covers axially aligned with the support tube are provided at both ends of the housing. This facilitates removal of a support tube which can be pushed from one end of the housing and out of the other end.**

**Preferably the housing has a transparent wall to enable visual detection of bubbles in permeate which has passed through the walls of the filter tubes. The transparent wall may be defined in the or one of the removable covers.**

**With such an arrangement, the integrity of the seals and the filter tubes may be readily checked without dismantling the filter by introducing a gas such as air to the side of the filter remote from the transparent housing wall. The gas is introduced at a pressure which is not sufficient to force the gas through the walls of the filter tubes or through the seals unless the filter has failed. Any structural failure in the filter will result in leakage which will be immediately apparent to an observer looking through the transparent wall of the housing as gas bubbles will appear in the flow. Thus leak detection and location is a simple matter, particularly when the filter is being used to process a transparent fluid such as water. All that is required is the periodic injection of air into the filter and a simple visual inspection.**

**The housing may support a plug slidable within one end of the support tube between first and second positions, the plug when in the first position obstructing an opening in the support tube to thereby obstruct fluid flow through a conduit communicating with that opening. Such an arrangement**

enables a tube bundle filter which has failed to be isolated from the system of which it forms part. The isolated unit can be replaced subsequently.

Preferably the or at least one of the removable covers supports at least one abutment which bears against one end of the support tube and thereby determines the axial position of the support tube within the housing. Preferably the or each removable cover comprises a disc supporting a circumferential seal, the seal bearing against the radially inner surface of the tubular housing. Alternatively the or each removable cover comprises a plate supporting a seal, the seal bearing against one end of the tubular housing.

The conduits may extend radially from the tubular housing, the or each conduit communicating with the space within the support tube around the filter tubes being connected to a passageway extending around the housing and communicating with radial holes in the housing wall. Alternatively, the conduits are defined by chambers across which the housing extends, the interior of the housing communicating with the conduits through radial holes in the housing wall. Alternatively the conduits may be defined by assemblies of interconnected housing components. Each housing component may receive one support tube, or where there are large numbers of tubes each housing component may receive a subgroup of those tubes, for example two or three support tubes. The housing components may be integrally moulded to define tubular sections which sealingly engage with the support tubes. The housing components may be clamped together or secured together by alternative means, for example adhesives. Each

**housing component may form a part of one conduit and communicate with one opening in the support tubes. Preferably, means are provided for venting air through the housing wall from at least one of the axially spaced regions which communicate with the conduits.**

**A plurality of housings may be provided each of which extends horizontally and receives a respective support tube, the housings being arranged in a series of horizontally spaced sections each of which includes a plurality of vertically spaced housings, and the housings of each section being connected to common vertically extending conduits. As an alternative, the housings may be arranged in a series of vertically spaced sections each of which includes a plurality of horizontally spaced housings, the housings of each section being connected to common horizontally extending conduits.**

**The invention also provides a filter comprising a bundle of filter tubes extending within and along the length of a support tube, a tubular housing for receiving at least one end of the support tube, and seals arranged between the filter tubes, support tube and housing such that fluid may flow in either direction along a flow path extending axially along the filter tubes, radially through the walls of the filter tubes, and through spaces defined within the support tube between the filter tubes, wherein the housing has a transparent wall aligned with the end of the support tube which it receives to enable a visual inspection of fluid flow through the filter.**

**The invention further provides a filter comprising a bundle of filter tubes extending within and along the length of a support tube, a housing for receiving one end of the support tube, and seals arranged between the filter tubes, support tube and housing such that fluid may flow in either direction along a flow path extending axially along the filter tubes, radially through the walls of the filter tubes, along through spaces defined within the support tube between the filter tubes, wherein the flow path includes at least one opening adjacent an end of the support tube, and the housing supports a plug slidable between a first position in which the or each opening is obstructed to block the flow path and a second position in which the plug does not obstruct the or each opening.**

**Embodiments of the present invention will now be described, by way of example, with reference to the accompany drawings, in which:**

**Figure 1 is a schematic representation of the structure of a water purification filter installation in accordance with the present invention;**

**Figure 2 is a schematic representation of the flow of water to be filtered, retentate and permeate in the structure represented in Figure 1;**

**Figure 3 is a side view of a filter tube bundle incorporated in the installation of Figure 1;**

**Figure 4 shows an axial section through a sealing tube incorporated in the installation of Figure 1;**

**Figure 5 is a section on line 5-5 of Figure 4;**

**Figure 6 is an axial section through one end of a support tube as illustrated in Figure 3, inserted into a sealing tube as illustrated in Figures 4 and 5, the location of associated housing components also being shown;**

**Figure 7 is a view on line 7-7 of Figure 6;**

**Figures 8 and 9 are schematic sectional views of a modified sealing tube arrangement which enables a faulty support tube to be isolated, Figure 8 showing the configuration in which the support tube is not isolated and Figure 9 showing the configuration when the support tube is isolated;**

**Figure 10 schematically represents a tool which may be used to actuate the mechanism illustrated in Figures 8 and 9.**

**Figures 11 and 12 are respectively side and end views of a further embodiment of the present invention;**

**Figure 13 is a schematic representation of the flow of water to be filtered, retentate and permeate in the structure represented in Figures 11 and 12;**

**Figure 14 is a side view of one end of a filter tube bundle incorporated in the installation of Figures 11 and 12;**

**Figure 15 is a sectional view in a horizontal plane through a sealing tube incorporated in the installation of Figures 11 and 12;**

**Figure 16 illustrates the structure which results from the insertion of the support tube of Figure 14 in the sealing tube of Figure 15;**

**Figure 17 is an end view of a removable cover incorporated in the structure shown in Figure 15;**

**Figures 18 and 19 are respectively schematic perspective and sectional views of an alternative structure similar to portions of that of Figure 1; and**

**Figure 20 is a schematic illustration of an alternative conduit arrangement to that of Figures 11 and 12.**

**Referring to Figure 1, the illustrated assembly comprises pipes 1 and 2 through which water to be filtered and retentate rejected by the filter is pumped in the direction of arrows 3, and pipes 4 and 5 which carry permeate in the direction of arrows 6. The pipe 1 is connected to vertically-extending box-section chambers defining passageways 7 through which water to be filtered flows vertically downwards as indicated by arrows 8. The pipe 2 is connected to vertically extending box-section chambers defining passageways 9 through which retentate flows vertically upwards in the direction of arrows 10. The passageways 7 and 9 are interconnected by tubular filter bundles 11. Permeate from the filter bundles 11 flows vertically upwards through box-section chambers defining passageways 12 and 13 in the direction of arrows 14 to the pipes 3 and 5. The walls of the passageways 13 supports removable transparent panels 15 the purpose of which is described in detail below.**

**When the filter is to be back-washed, clean water is pumped downwards through passageways 12 and 13 and the filters are flushed out by pumping water through the filters from passageway 9 to passageway 7. The installation will be operated in accordance with a predetermined cycle such that the direction of**

**flow of water through the system is periodically reversed to wash out particles that have accumulated on the filter tubes.**

**Referring to Figure 2, this schematically represents the flow through the structure of one of the vertical sections of the structure of Figure 1 incorporating six filter bundles 11. During normal operation, the flow of water to be filtered, retentate and filtrate is indicated by arrows drawn in full line. The direction of flow during backwashing is indicated by arrows drawn in broken lines. It will be noted that each filter bundle is represented as an outer support tube within which a single filter tube is supported, the filter tube extending through seals adjacent the ends of the support tube. It will be appreciated that each filter bundle will in fact incorporate many thousands of filter tubes.**

**The structure illustrated in Figure 1 comprises four vertical arrays of six filter bundles to give a total of twenty four bundles, but it will be appreciated that as many arrays could be provided as is required with each array including as many filter bundles as desired.**

**Figure 3 illustrates one of the filter tube bundles 11 of Figure 1. The bundle comprises a PVC support tube 16 which is open at both ends. Two pairs of seals are supported on the tube 16, the seals of each pair being axially spaced apart adjacent a respective end of the tube 16. Each seal comprises a plastic O-ring mount 17 which is bonded to the tube 16 and supports an O-ring 18. The interior of the tube 16 is filled with a bundle of hollow fibres 19 which as described below in greater detail extends through seals axially aligned with the**

end most seal mounts 17. An array of eighteen apertures 20 is formed in the support tube 16 between the O-ring mounts 17 of each pair of seals such that each aperture 20 communicates with the interior of the tube 16 through which the fibres 19 extend.

Figures 4 and 5 illustrate a sealing tube one of which receives each end of the filter tube bundle shown in Figure 3. Thus two sealing tubes together define a housing in which a single support tube is received. Each sealing tube comprises a tubular body 21 in which two arrays of apertures 22 and 23 are formed. Bearing surfaces 24 are machined on the inner surface of the sealing tube 21, the bearing surfaces 24 being intended to contact respective O-rings 18 on the end of a filter tube bundle of the type shown in Figure 3. The sealing tube 21 is welded to three parallel walls 25, 26 and 27, the space between walls 25 and 26 defining the passageway 9 of Figure 1 and the space between walls 26 and 27 defining the passageway 13 of Figure 1. Walls 28 and 29 link the walls 25, 26 and 27 to form box-section chambers one of which defines a passageway which communicates with the apertures 22 and the other of which defines a passageway which communicates with the apertures 23. The sealing tube 21 projects through the wall 27 and is sealed by transparent panel 15 (see Fig. 1) secured in position by bolts 30. An appropriate sealing gasket will be provided between the end of the sealing tube 21 and the transparent panel 15. The transparent panel will preferably be formed from a sheet of polycarbonate.

Referring to Figures 6 and 7, this shows a support tube 16 engaged in a sealing tube 21 positioned uppermost in a vertical array of filter tube bundles. Water to be filtered is introduced through a three inch flange 31 in the direction of arrow 32, passes through the apertures 22 in the sealing tube 21 so as to enter the space around the support tube 16 between the sealing rings 18, passes through the openings 20 in the tube 16, and enters the space defined inside the support tube 16 around the filter tubes 19. It will be seen that the tubes 19 pass through an epoxy resin seal 33 which prevents liquid within the support tube 16 leaving that tube except as a result of being forced through the walls of the filter tubes 19 and travelling axially along the filter tubes. Permeate which has passed through the walls of the filter tubes emerges from the ends of those tubes into the space which communicates through the openings 23 with the conduit defined between the walls 26 and 27. That conduit is in communication with a two inch flange 34 via pipe 35. Thus a flow path is established from the flange 31, into a first conduit defined between walls 25 and 26, from that first conduit into the support tube 16, through the walls of the filter tubes 19 to reach the interior of the sealing tube adjacent the transparent end plate 15, and then into a second conduit defined between walls 26, 27 with which the pipe 35 communicates. The walls 25, 26, 27, 28 and 29, the sealing tubes 21 and the flanges 31 and 34 are defined by a welded assembly the integrity of which once installed can be relied upon. If any leakage is likely to occur it will result from a failure of the seals defined by the O-rings 18, or failure of individual fibre filter tubes 19, or failure

of the seal 33. The assembly may be tested for leakage however relatively easily by injecting air through the flange 31 at a pressure insufficient to cause air to pass through any of the seals or components of the assembly. In the event of a leak, air will be forced through the assembly and as a result bubbles will appear inside the sealing tube 21 in the region around which the openings 23 are formed. Any such bubbles can be readily seen through the transparent end panel 15. Not only will it be immediately apparent that a leak has occurred, it will also be apparent that the leak comes from components associated with an individual filter tube bundle which may then be replaced as necessary.

The housings which are formed by the walls 25 to 28, the sealing tubes 21 and the associated end plates and flanges 31 and 34 may be readily assembled from stainless steel plate. For example, the walls 25, 26 and 27 may be formed from single sheets of stainless steel from which circular apertures have been punched and into which the sealing tubes 21 are inserted. The sealing tubes 21 are then welded in position and appropriate side and end pieces are welded thereto to form the required box-sections. These housings form components which are often referred to as "headers" in that they receive the heads of individual filter tube bundles 11 (see Figure 1). The headers may be mounted on a simple steel frame (not shown), the headers being secured in position by adjustable bolts to allow for the precise alignment of the different components. The headers are mounted on the frame at an appropriate separation to receive the filter tube bundles. To insert each filter tube bundle, the O-rings 18 are

removed, the transparent plate 15 is removed from one header, and the support tube 16 is pushed through the header from which the panel 15 has been removed towards the other header. The O-rings 18 are then placed over the O-ring mounts 17 at both ends of the support tube 16 and the assembly is then pushed into the two headers until the O-rings 18 bear against the surfaces 24. The assemblies may be pushed home using a simple tool (not shown) incorporating a screw and engageable with the box-sections of the headers. A spring clip (not shown) may be inserted to prevent subsequent axial movement of the support tube 16 relative to the headers. The transparent panel 15 is then secured in position and the assembly is ready for use.

The illustrated system has the advantage of simplicity. The only components which require careful machining are the sealing tubes 21. In large quantities these components may be manufactured at a relatively low cost. The O-rings 18 seal on machined surfaces which will not distort and therefore should be reliable. All of the seals can be tested without dismantling by injecting gas such as air. The interconnection of adjacent headers enables a high density of filter tube bundles to be installed in a relatively small volume. Furthermore the structure can be easily modified to increase or decrease the number of filter tube bundles in any particular installation. The support tubes 16 define a continuous smooth PVC internal surface except immediately adjacent the support tube ends. This means that the filter tubes are well supported either by the seals adjacent the ends of the support tube or by the smooth interior surface of that tube. Filter

tube damage is therefore unlikely. As the only steel components are the headers, the weight of the system will be acceptable, this being of significance in terms of the machinery and labour required to install and maintain systems. As the O-rings 18 only have to travel a short distance, typically 6 inches, during final assembly, and a screw-based tool may be used, a steady pressure may be applied to the O-rings which will reduce the likelihood of O-ring damage.

In the embodiment of Figures 1 to 7, leakage can be readily detected and located. Once a leak has been detected and located however, the installation must be shut down pending repair. The arrangement of Figures 8 to 10 makes it possible to isolate any filter tube bundle which is leaking without disabling the entire installation within which that bundle is incorporated.

Figures 8 and 9 show views of a modified arrangement similar to the views shown in Figures 6 and 7. The same reference numerals are used where appropriate. In the case of the embodiment of Figures 8 and 9, the sealing tube 21 has been extended beyond the wall 27 so as to define a projecting tubular portion which receives a tubular piston 36 provided with sealing rings 37 and 38. The piston 36 incorporates a transparent end panel 39 to which a screw 40 is attached. The piston 36 may be positioned as shown in Figure 8 such that the openings 23 are not obstructed and the operation of the device is exactly as described above with reference to Figures 1 to 7. Alternatively the piston 36 may be moved to the position shown in Figure 9, in which case the openings 23 are isolated from the rest of the assembly by the O-rings 37 and 38. In that

configuration any retentate leaking through any one of the seals of the insert of which the tube 16 forms a part cannot enter the permeate side of the installation. Thus an operator of the device could detect a leak by visual inspection through the transparent panel 39 and isolate that leak from the permeate side of the installation simply by rotation of the screw 40.

Figure 10 schematically represents an insertion and extraction tool for controlling the position of the piston 36 of Figures 8 and 9. It will be seen that the screw 40 is attached to a simple drive handle 41 which in turn is connected to a support frame 42 that is engageable with the header in which the transparent panel 15 is supported. The blocking piston 36 may be secured in position by any appropriate means, for example a transparent plate 43 as shown in Figures 8 and 9 through which the screw 40 extends, or a simple circlip which prevents the piston being forced out of the sealing tube 21. In the latter case the piston 36 may be positioned simply by pushing it axially and then holding it in its inserted position by an appropriate clip of some form.

Referring now to Figures 11 to 17, an alternative embodiment to that illustrated in Figures 1 to 10 will be described. Whereas in the structure of Figure 1 individual support tubes project across box-section chambers and communicate with the interior of those chambers through radial holes in the sealing tubes, in the arrangement of Figure 11 individual support tubes communicate with radially extending conduits each of which communicates with a vertically extending tube. Furthermore, whereas in the arrangement of

Figures 1 to 10 the structure operates such that the side of the filter tubes exposed to the water to be filtered is swept by an axial flow of that water through the support tube, in the arrangement of Figure 11 each tube bundle acts as a "dead-end" filter. In addition, whereas the schematic representation of fluid flows shown in Figure 2 represents the flow through a vertical array of six tube bundles, Figure 13 represents the flow through a horizontal array of five tube bundles.

Referring to Figures 11, 12 and 13 in detail, the illustrated structure comprises five vertical arrays of tube bundles 41, each vertical array incorporating six tube bundles such that the installation supports a total of thirty tube bundles. Raw water is supplied through a conduit 42, permeate is removed through a conduit 43, backwash fluid is supplied through a conduit 44, and backwashed fluid is delivered to a conduit 45. The conduit 45 communicates with three vertically extending conduits 46, the conduit 42 communicates with three vertically extending conduits 47, the conduit 43 communicates with three vertically extending conduits 48, and the conduit 44 communicates with three vertically extending conduits 49.

Figure 13 shows the flow to the uppermost layer of five filter bundles 41. The connections to all six layers of the structure are identical. During normal operation, raw water is pumped in through conduit 42, enters the support tubes around the filter tubes, passes through the walls of the filter tubes, moves axially to the ends of the filter tubes remote from the conduit 42, and travels from the

ends of the tube bundles to the conduit 43. Particulates in the raw water therefore build up on the surface of the individual filter tubes. The system is periodically flushed out by closing valves in conduits 42 and 43, opening valves in conduits 44 and 45, and pumping backwash water into conduit 44. The backwash water enters the individual filter tubes, flows radially outwards through the walls of individual filter tubes thereby lifting deposited particulates away from the tubes, and the particulates then flow into conduit 45.

Figure 11 shows a flow control valve 50 provided on the conduit 43. A similar valve is provided on conduit 44. Figure 12 shows valve 51 and 52 on conduits 42 and 45. These valves are controlled as appropriate to achieve the operational conditions described above.

The detailed interconnection of the tube bundles with the conduits shown in Figure 13 will now be described with reference to Figures 14 to 17. Figure 14 shows one end of an individual tube bundle 41. Three annular sealing rings 53, 54 and 55 are received within the grooves defined in the outer surface of the bundle. Each of the sealing rings is of C-shaped section and in its free state projects radially outwards beyond the outermost surface of the tube bundle. Apertures 56 which may be arranged for example in two rows as shown extend radially through the wall of the tube bundle, the apertures 56 being located between the seals 54 and 55. The apertures 56 communicate with the internal space defined in the tube bundle and thus correspond in function to the apertures 20 in the embodiment of Figures 1 to 10. Individual filter tubes extend

beneath the apertures 56 and through a sealing means located in the end of the tube bundle radially inwards of and axially between the seals 53 and 54. Thus the axial end of the tube bundle is in operation isolated from the apertures 56.

Each end of each tube bundle is received in a sealing tube of the type illustrated in Figure 15. The sealing tube defines a smooth inner surface 57 and has flanges 58 and 59 connected thereto. The flange 59 communicates with an annular passageway 60 extending around the sealing tube, that annular passageway communicating with radial holes 61 in the sealing tube. Air escape holes 62 and leakage bleed holes 63 are defined in the upper and lowermost sections of each sealing tube. An end cover 64 supporting a handle 65 is secured within the end of the sealing tube by bolts (not shown) extending through lugs 66 and engaging lugs (not shown) welded to the outer surface of the sealing tube. A circumferential O-ring 67 forms a secure seal between the end cap 64 and the interior surface of the sealing tube. The end cap also supports projecting abutments 68 which extend axially into the interior of the sealing tube.

Figure 16 shows the end of the tube bundle of Figure 14 inserted into the sealing tube of Figure 15. It will be noted that the abutments 68 ensure that the end of the tube bundle is maintained at a predetermined distance from the end cap 64. As a result the apertures 56 are aligned with the flange 59 and the flange 58 communicates with an empty space in the end of the sealing tube which is in communication with the open ends of the filter tubes within the tube bundle. The air escape holes 62 are aligned with the flange 58 and as a result any air

which may enter that portion of the system can escape vertically. Similarly, the air escape holes 62 are aligned with the flange 59 to ensure that air can escape from that portion of the system. The outermost bleed hole 63 is axially aligned with a space defined between the seals 53 and 54 such that if any fluid leaks past either one of those seals it can escape from within the sealing tube and its escape can be detected to indicate seal failure. Similarly the innermost bleed hole will receive any fluid which leaks past the seal 55. Appropriate detectors can be positioned to detect any fluid leaking through the bleed holes 63 to provide an early indication of seal failure.

Referring again to Figures 11 and 12, the air escape holes which are located at the bottom of the five lowermost sealing tubes are plugged. The uppermost air escape holes are linked by pipes 69 to the next immediately adjacent sealing tubes such that the connection continues up through the layers of support tubes, the air escape holes of the sealing tubes of the uppermost layer of tube bundles being connected by a pipe 70 to an air escape manifold 71. To prevent any risk of cross-contamination, the air release system from the raw water side of the filter is separate from the air release system from the permeate side of the filter. Thus air locks can be readily eliminated from the system despite the fact that the conduits communicating with the individual tube bundles are lower than the uppermost portions of the interior of each tube bundle.

Referring now to Figure 18, an alternative structure to that illustrated in Figure 1 for vertically interconnecting adjacent support tubes is illustrated. As illustrated, support tubes 68 extend through a first housing component 69 into a second housing component 70. The support tubes 68 are aligned with removable end caps 71 which once removed enable the insertion of the support tube therethrough. The end cap 71 may be transparent to enable the inspection of the interior of the housing component 70.

As shown in Figure 19 which is a vertical section through the axis of one support tube, a housing component 69, a housing component 70 and vertically adjacent housing components, the housing components 69 and 70 are identical integral mouldings each defining an upper opening 72, a lower opening 73, and tubular portions 74 which are either closed by an end cap 71 or through which the support tube 68 extends. Seals schematically represented by O-rings 75 are positioned between interengaged components such that the space within the housing components 69 defines a conduit communicating with the interior of the support tube through a radial hole 76 in that tube. Similarly, the interior of the housing component 70 and the vertically adjacent housing components define a further conduit in communication with the open ends of the filter tubes within the support tubes.

The adoption of a modularised structure such as that illustrated in Figures 18 and 19 enables the use of a limited range of different components to

form filter structures of very different size. Thus filters can be manufactured to meet a wide range of applications.

Referring now to Figure 20, this shows an alternative arrangement of conduits to that shown in Figures 11 and 12. It is believed that a greater density of support tubes can be arranged in the configuration of Figure 20 as compared with that of Figures 11 and 12.

In Figure 20, individual support tubes are represented by circles 77. Details of the housings which receive those support tubes are not shown but each end of each support tube is connected to a branch conduit 78 which extends vertically upwards and communicates with a horizontally extending conduit 79. That conduit 79 is in turn connected to a vertical conduit 80. Similarly each end of each support tube is connected by a branch conduit 81 which extends downwards to a conduit 82. That conduit is in turn connected to a conduit 83. With the arrangement of Figure 20, the horizontal spacing between adjacent support tubes can be very small.

In the arrangement of Figure 20 vertically extending branch conduits 78 serve as air escape pathways, but it would still be necessary to provide air escape passages extending vertically upwards from the regions of the support tubes communicating with the conduits 82.

CLAIMS

1. **A filter comprising at least one bundle of open-ended filter tubes housed within and extending along the length of a support tube, sealing means arranged at each end of the support tube such that the filter tubes extend therethrough, the sealing means preventing axial flow through the ends of the support tube except through the filter tubes, a tubular housing which receives the support tube, at least two conduits communicating with respective openings in the housing, axially spaced annular seals located between the support tube and the housing to divide the space defined between the support tube and housing into axially spaced regions which communicate with respective conduits, at least two openings in the support tube located to communicate with respective conduits through respective regions of the space between the housing and support tube, at least one of the openings in the support tube communicating with the open ends of the filter tubes, at least one of the openings in the support tube communicating with the space within the support tube around the filter tubes and between the sealing means, and the housing having a removable cover which when removed leaves an aperture axially aligned with the support tube to enable the insertion and removal of the support tube in the axial direction.**

2. A filter according to claim 1, wherein the housing comprises two axially aligned sealing tubes each of which receives a respective end of the support tube, each sealing tube being connected to at least one conduit.
3. A filter according to claims 1 or 2, wherein the support tube is open ended.
4. A filter according to claim 1, 2 or 3, wherein the housing is connected to first and second conduits which communicate with respective ends of the filter tubes and third and fourth conduits which communicate with opposite ends of the space defined within the tubular support between the sealing means.
5. A filter according to claim 4, comprising means for directing a flow of fluid to be filtered into the third conduit and out of the fourth conduit such that particles deposited on the filter tubes are flushed out of the support tube to the fourth conduit.
6. A filter according to claim 4, comprising means for directing a flow of fluid to be filtered into one or both of the third and fourth conduits and removing permeate from one or both of the first and second conduits, and

**means for backwashing the filter tubes by directing a flow of backwash fluid into one or both of the first and second conduits and removing backwashed material from one or both of the third and fourth conduits.**

7. **A filter according to any preceding claim, wherein the annular seals are retained in circumferential grooves defined in the outer surface of the support tube.**
8. **A filter according to any preceding claim, wherein at least one annular seal comprises a pair of axially spaced seals, and a drain hole is defined in the housing between the pair of seals to enable fluid leaking past either of the pair of seals to escape from the housing.**
9. **A filter according to any preceding claim, wherein removable covers axially aligned with the support tube are provided at both ends of the housing.**
10. **A filter according to any preceding claim, wherein the housing has a transparent wall to enable visual detection of bubbles in permeate which has passed through the walls of the filter tubes.**

11. **A filter according to claim 10, wherein the transparent wall is defined in the or one of the removable covers.**
12. **A filter according to any preceding claim, wherein the housing supports a plug slidable within one end of the support tube between first and second positions, the plug when in the first position obstructing an opening in the support tube to thereby obstruct fluid flow through a conduit communicating with that opening.**
13. **A filter according to any preceding claim, wherein the or at least one of the removable covers supports at least one abutment which bears against one end of the support tube and thereby determines the axial position of the support tube within the housing.**
14. **A filter according to any preceding claim, wherein the or each removable cover comprises a disc supporting circumferential seal, the seal bearing against the radially inner surface of the tubular housing.**
15. **A filter according to any one of claims 1 to 13, wherein the or each removable cover comprises a plate supporting a seal, the seal bearing against one end of the tubular housing.**

16. A filter according to any preceding claim, wherein the conduits extend radially from the tubular housing, the or each conduit communicating with the space within the support tube around the filter tubes being connected to a passageway extending around the housing and communicating with radial holes in the housing wall.
17. A filter according to any preceding claim, wherein the conduits are defined by chambers across which the housing extends, the interior of the housing communicating with the conduits through radial holes in the housing wall.
18. A filter according to any preceding claim, wherein the conduits are defined by assemblies of interconnected housing components each of which receives one or a sub-group of the support tubes.
19. A filter according to claim 18, wherein the housing components are integrally moulded to define tubular sections which sealingly engage with the support tubes.
20. A filter according to claim 18 or 19, wherein the housing components are clamped together.

21. A filter according to claim 18, 19 or 20, wherein each housing component forms a part of one conduit and communicates with one opening in the support tube.
22. A filter according to any preceding claim, comprising means for venting air through the housing wall from at least one of the axially spaced regions which communicate with the conduits.
23. A filter according to any preceding claim, comprising a plurality of housings each of which extends horizontally and receives a respective support tube, the housings being arranged in a series of horizontally spaced sections each of which includes a plurality of vertically spaced housings, and the housings of each section being connected to common vertically extending conduits.
24. A filter according to any one of claims 1 to 22, comprising a plurality of housings each of which extends horizontally and receives a respective support tube, the housings being arranged in a series of vertically spaced sections each of which includes a plurality of horizontally spaced housings, and the housings of each section being connected to common horizontally extending conduits.

- 25. A filter comprising a bundle of filter tubes extending within and along the length of a support tube, a tubular housing for receiving at least one end of the support tube, and seals arranged between the filter tubes, support tube and housing such that fluid may flow in either direction along a flow path extending axially along the filter tubes, radially through the walls of the filter tubes, and through spaces defined within the support tube between the filter tubes, wherein the housing has a transparent wall aligned with the end of the support tube which it receives to enable a visual inspection of fluid flow through the filter.**
- 26. A filter according to claim 25, wherein the filter tubes open into the housing through a seal formed adjacent the end of the support tube received by the housing, and the flow path extends through at least one radial opening in the support tube on the side of the seal remote from the end of the tubular support.**
- 27. A filter according to claim 25, wherein each end of the support tube is received in the housing, the filter tubes open into the housing through seals formed adjacent the ends of the support tubes, and the flow path extends through radial openings in the support tube which are located between the seals through which the filter tubes extend.**

28. A filter according to claim 25, wherein each end of the support tube is received in the housing, the filter tubes open into the housing through seals formed adjacent the ends of the support tubes, and the flow path extends through radial openings in the support tube which are located between the seals through which the filter tubes extend.
29. A filter according to claim 26 or 27, wherein the or each housing comprises a sealing tube which receives a support tube and extends across a first conduit into a second conduit, the second communicating with the open ends of the filter tubes, the first conduit communicating through at least one further opening in the sealing tube which is isolated from the first conduit by one of the axially spaced seals located between the sealing tube and the support tube.
30. A filter according to claim 29, comprising a plug mounted in the housing and displaceable between a first position in which the or each further opening is obstructed to block the flow path and a second position in which the plug does not obstruct the or each further opening.
31. A filter according to claim 28, 29 or 30, comprising an array of support tubes each mounted in a respective sealing tube supported by a common housing defining the first and second conduits.

32. A filter according to claim 31, wherein the common housing is elongate and of rectangular cross-section such that the sealing tubes are arranged in a linear array.
33. A filter according to any one of claims 25 to 32, wherein the transparent wall is defined by a removable panel covering an opening in the or each housing.
34. A filter according to claim 33, wherein the opening in the or at least one housing is dimensioned to enable the insertion of the support tube therethrough.
35. A filter comprising a bundle of filter tubes extending within and along the length of a support tube, a housing for receiving one end of the support tube, and seals arranged between the filter tubes, support tube and housing such that fluid may flow in either direction along a flow pattern extending axially along the filter tubes, radially through the walls of the filter tubes, and through spaced defined within the support tube between the filter tubes, wherein the flow path includes at least one opening adjacent an end of the support tube, and the housing supports a plug slidable between a first position in which the or each opening is

**obstructed to block the flow path and a second position in which the plug does not obstruct the or each opening.**

- 36. A filter substantially as hereinbefore described with reference to Figures 1 to 10, Figures 11 to 17, Figures 18 and 19, or Figure 20 of the accompanying drawings.**

1-11

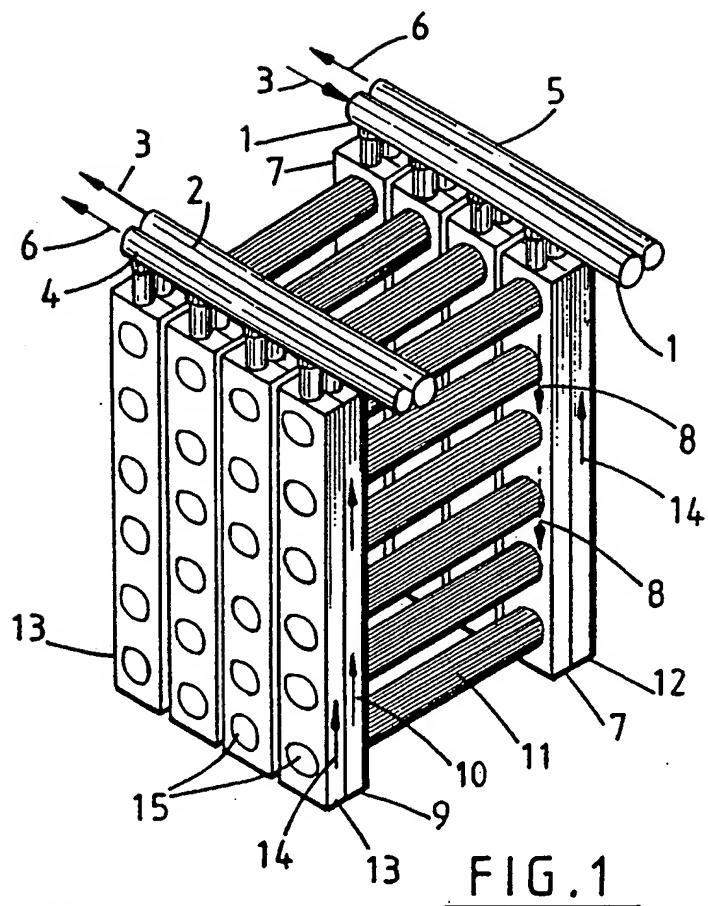


FIG. 1

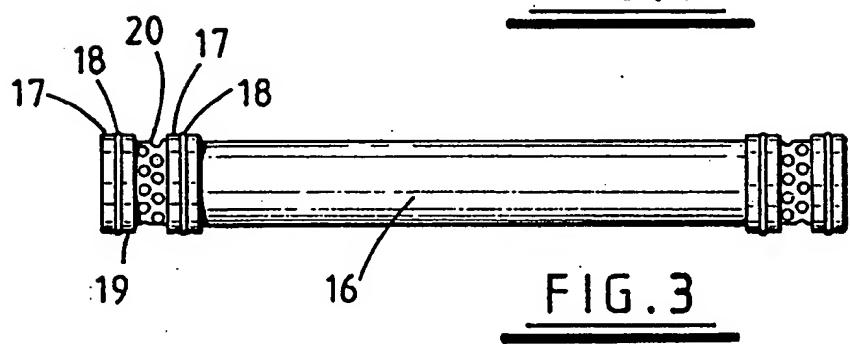
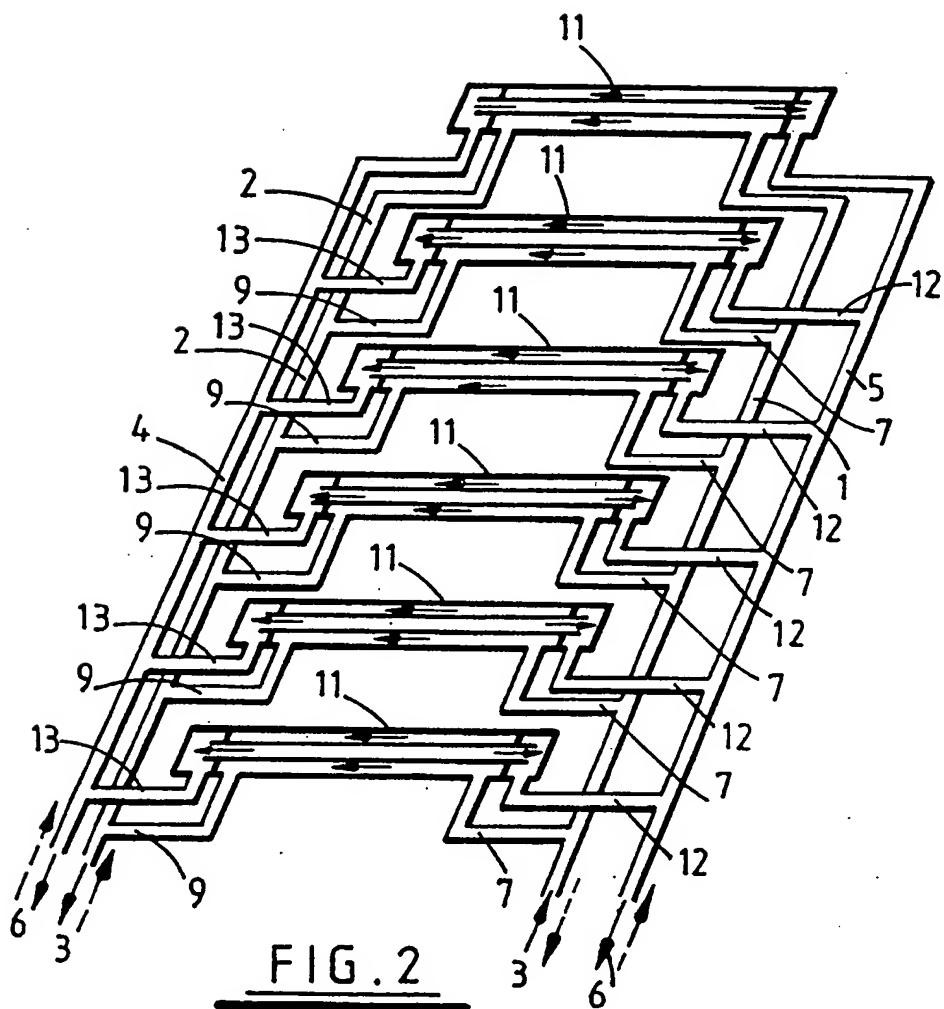
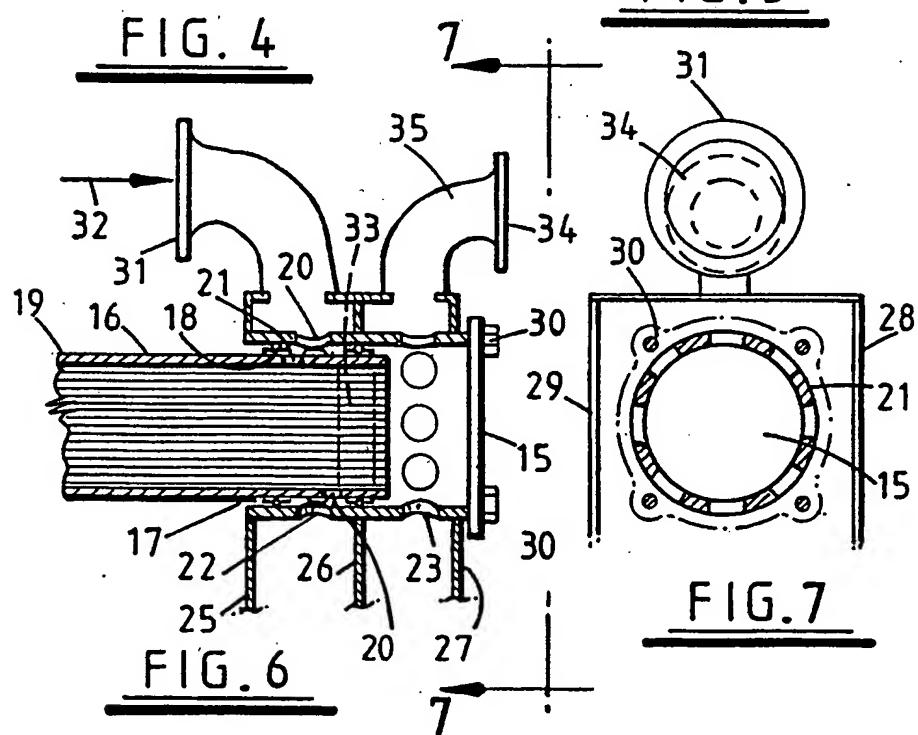
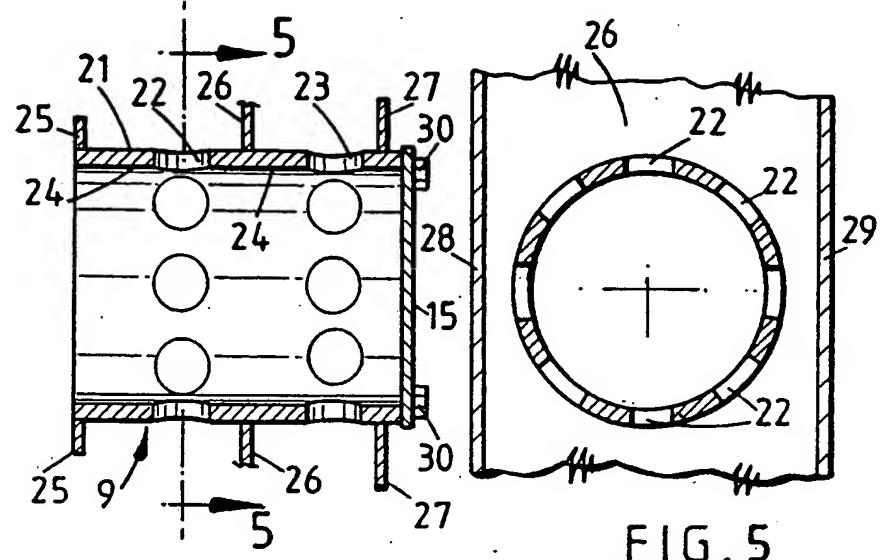
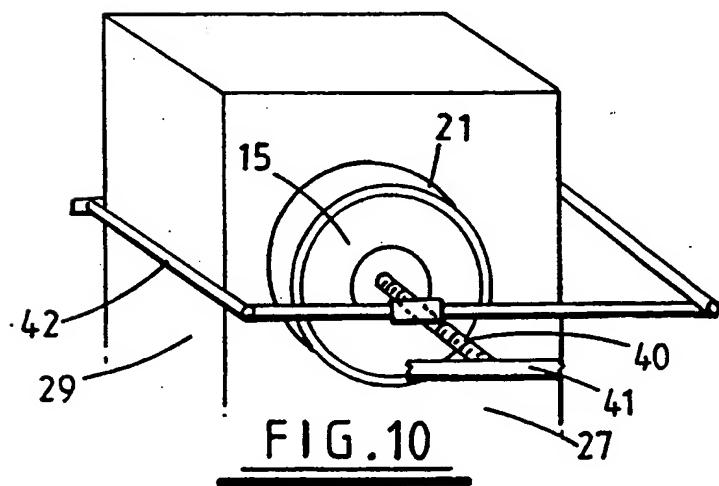
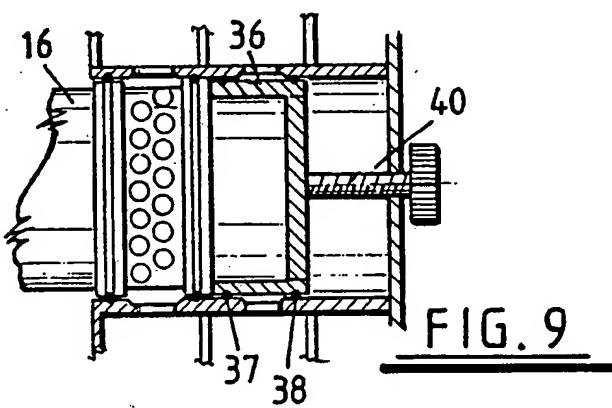
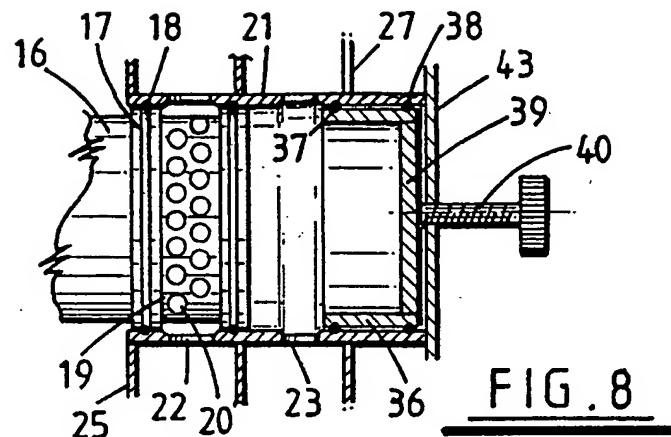


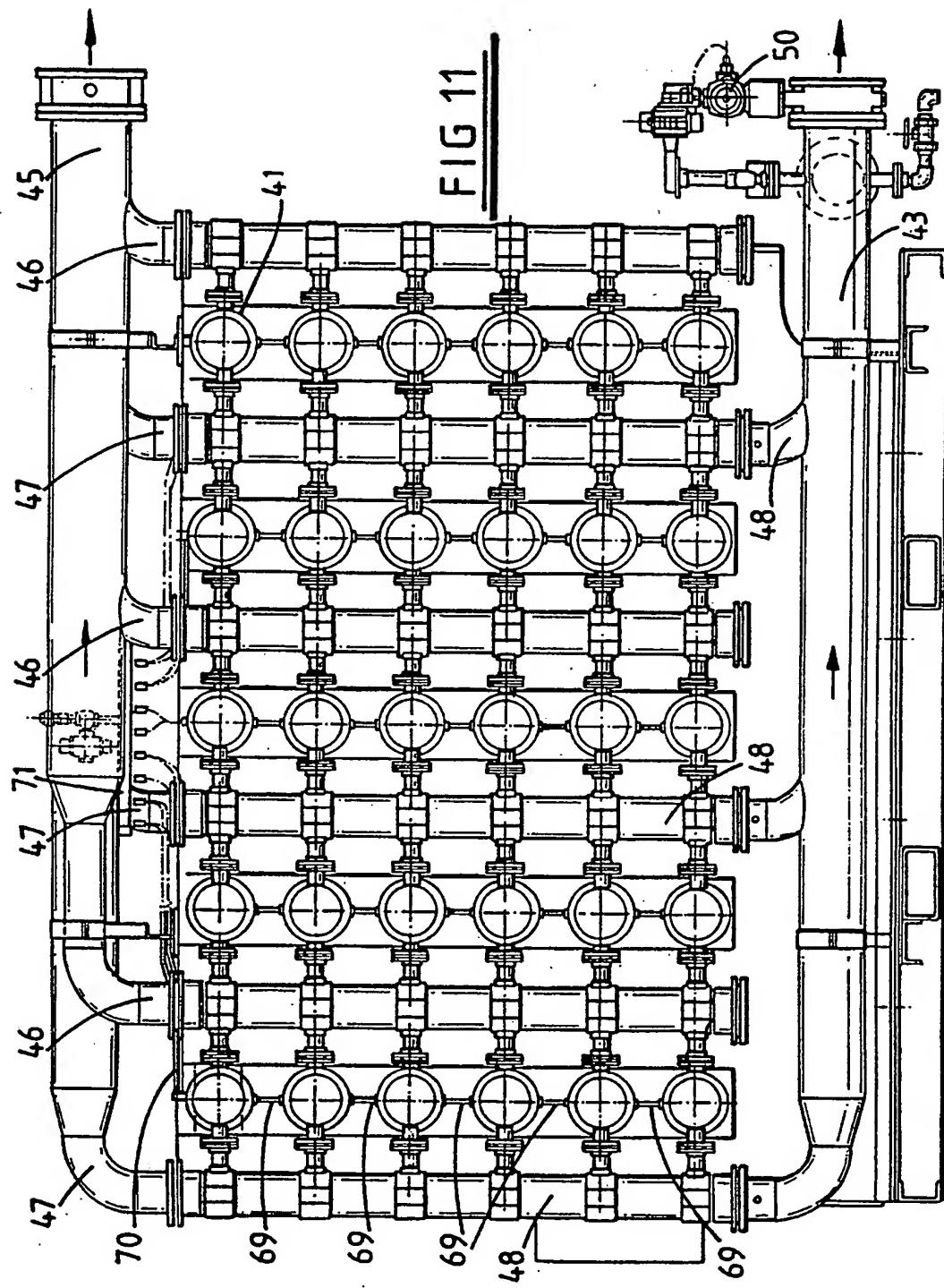
FIG. 3

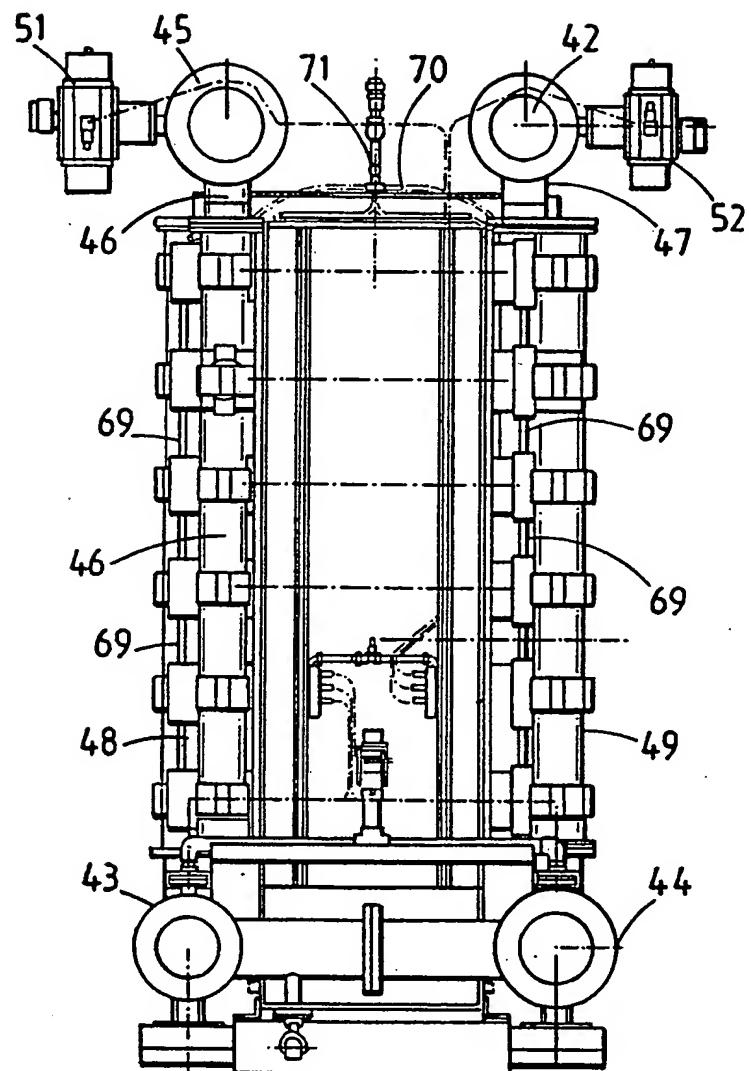
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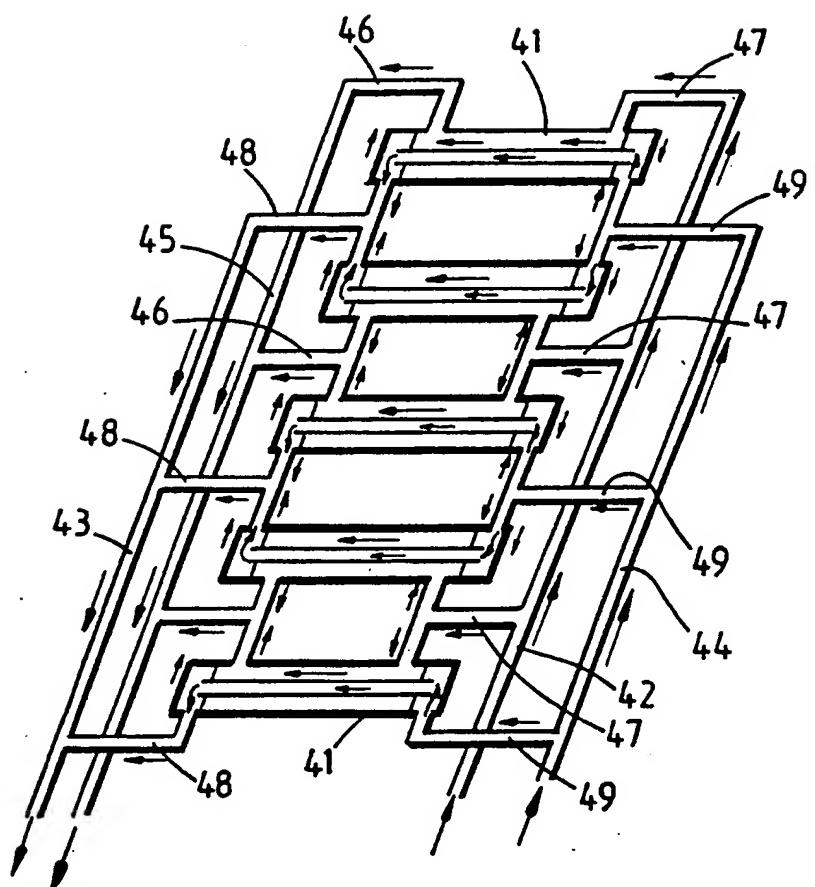
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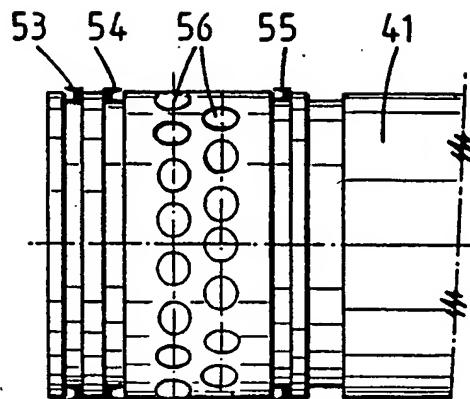
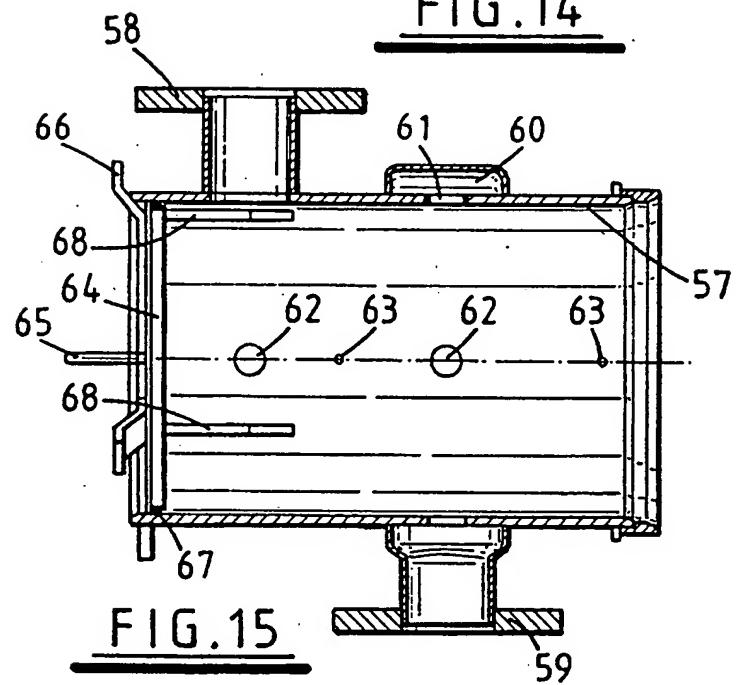
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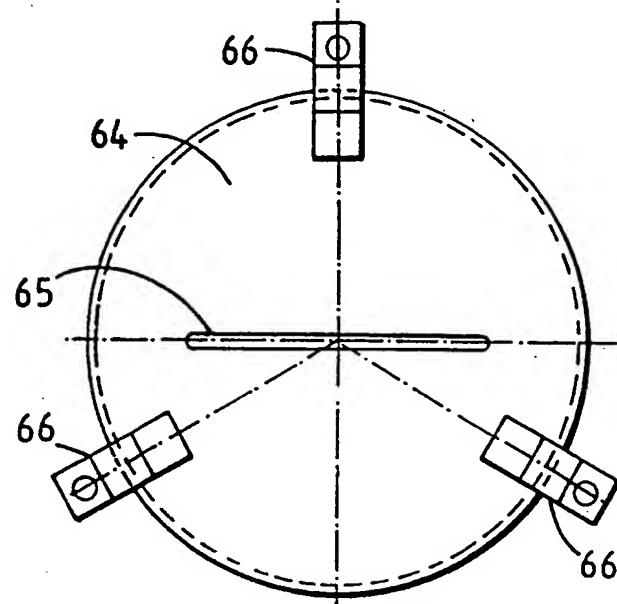
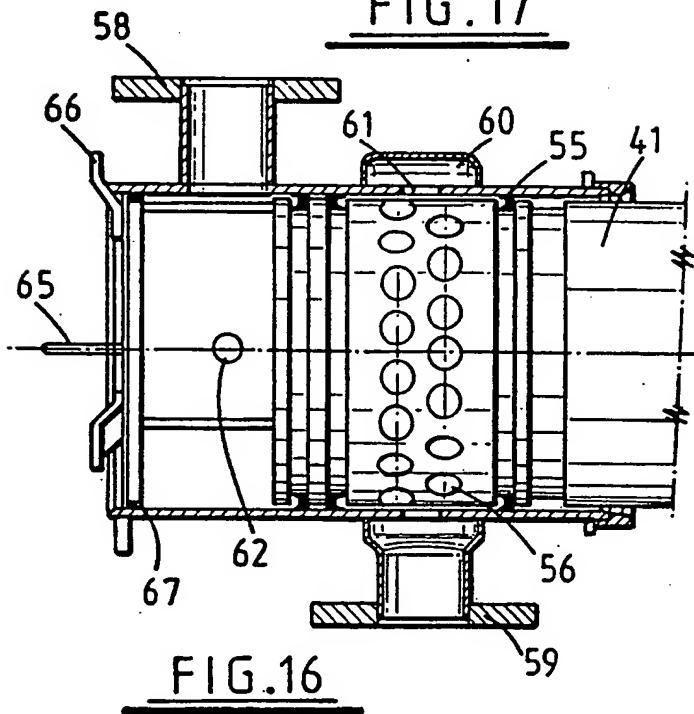


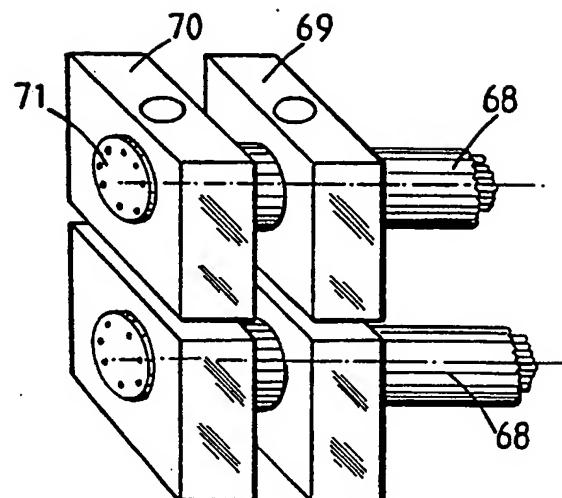
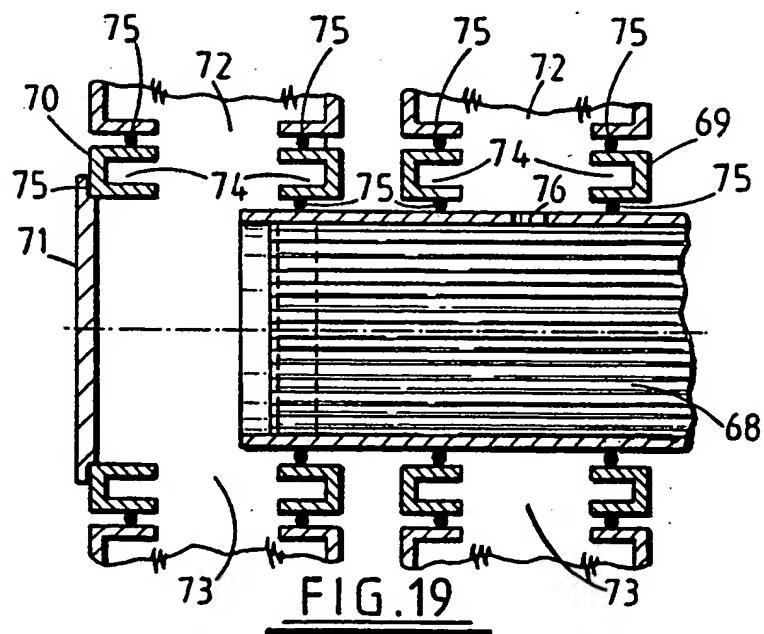
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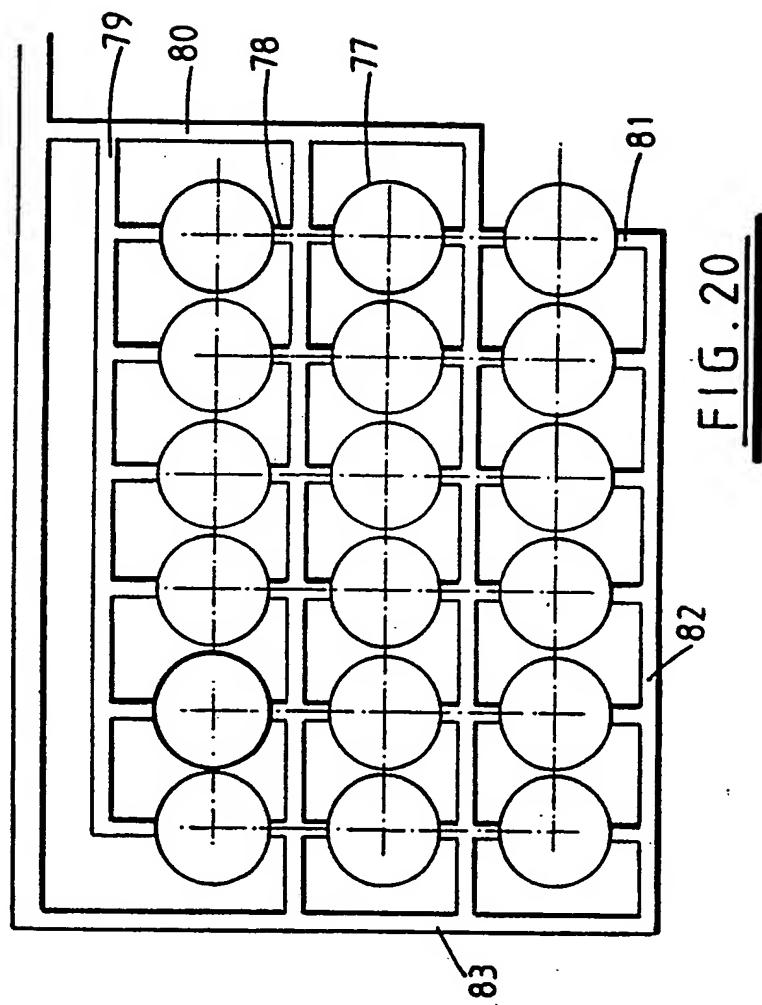
6-11FIG. 12

7-11FIG.13

8-11FIG. 14FIG. 15

9-11FIG. 17FIG. 16

10-11FIG. 18FIG. 19

11-11

## INTERNATIONAL SEARCH REPORT

International Application No  
PCT/GB 96/01395A. CLASSIFICATION OF SUBJECT MATTER  
IPC 6 B01D63/06 B01D63/04 B01D65/10

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)  
IPC 6 B01D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO,A,91 16124 (MEMTEC LTD) 31 October 1991 see the whole document ---	1
A	EP,A,0 203 378 (AKZO GMBH) 3 December 1986 SEE ESPECIALLY FIGURE 13 ---	1
A	DE,A,39 16 511 (SEITZ-FILTER-WERKE) 13 December 1990 see the whole document ---	1
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Date of the actual completion of the international search

Date of mailing of the international search report

18 September 1996

25.09.96

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## INTERNATIONAL SEARCH REPORT

International Application No  
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